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W. L. THAYER

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A SERVO-CONTROLLED BIAXIAL TEST SYSTEM

W. L. Thayer
Lawrence Livermore National Laboratory
Livermore, California 94550

A large test program requiring axial torsion tests was submitted to the Materials Test and Evaluation Section of the Engineering Sciences Division by the Chemistry Department. The objective of these tests was to provide insight with regard to the fundamental aspects of plastic deformation and hardening of nickel. These tests will also provide the constants necessary for a constitutive equation for use in weld modeling. The weld models will attempt to predict residual stresses in nickel welds.

The test program consisted of approximately 70 specimens of high purity nickel to be tested in torsion over a large temperature range (RT — 900° C) at a strain rate of about 1×10^{-4} in./in./sec to steady state at each temperature. After having attained steady state, the strain-rate-reversal (Bauschinger test) and incremental-changes-in-strain-rate tests (10^{-4} to 2×10^{-3} in./in./sec) at constant structure will be conducted. Additional tests such as transient backstress and yield surface distortion (using multi-axial stress states) will be carried out.

This particular request required a biaxial test machine capable of more than 360° rotation in torsion. Temperature capabilities, atmosphere control, and a control system were also needed whereby the machine could be operated in torsion using strain control. Such a machine did not commercially exist so it was necessary to build one. The basic unit chosen was a 20K Servo-Electric Hydraulic Test Machine to which we added a simple anti-rotation fixture for the ram. This constituted the axial portion of the system. To this machine was added a complete torsion capability (see Fig. 1).

At the lowest required strain rate of 1×10^{-4} in./in./sec, the actuator could not develop the minimum starting torque necessary to overcome the inertia of the rotary actuator. During testing, it was ascertained the actuator stalled at a maximum torque of 164 in.-lbs. This torque was insufficient to strain nickel at room temperature. Both of these problems were solved by installing a gear reduction box with a 60:1 ratio.

The next and largest obstacle was the design and installation of a system to measure the shear strain (γ) over a one-inch gauge section inside a furnace and to use this signal to control the hydraulic torsion apparatus. On our first attempt, we mounted two pulleys one inch apart at the center section of a specimen 9.75 inches long and 0.250 inch in diameter. This defined the gauge section. Each pulley was then connected to a wire-wound potentiometer outside the furnace by means of an endless 0.030-inch platinum wire. As the specimen rotated, the wire turned the potentiometer and the output was measured. The potentiometers were wired in such a manner that they measured the differential output. That is, they measured only the amount of strain introduced into the specimen over the one-inch gauge length. This signal was recorded for data and also sent to the control system, completing the feedback control loop.

Unfortunately, the wire-wound potentiometers did not operate smoothly enough to control the servo-loop. As the wiper passed the wire windings, it would jump from wire to wire. This resulted in an unsatisfactory non-uniform strain rate. After extensive testing conclusively proved the wire-wound potentiometers could not do the job, a pair of special potentiometers were purchased to solve the problem.

These potentiometers (trade name of Durapots) have no internal touching parts. The manner of their operation is proprietary, but they appear to work on a magnetic field principle and are very accurate. Durapots are capable of only one revolution during which the output signal generated goes from zero to ten volts DC. At this point, the output signal goes back to zero volts and restarts. To solve this problem, a small set of pulleys and a gear reduction box were installed. This system allows the specimen to twist ten times to one revolution of the Durapot (see Fig. 2).

Gripping the specimen was accomplished by using a 0.250 inch compression collet on each end. These collets were satisfactory for elevated temperature tests where the material strength was lower when temperature is more than 200° C, but they slipped during room temperature tests. For room temperature tests, the diameter of the specimen was reduced to 0.190 inch to lower the necessary torque to deform the specimen. The temperature requirements were met by the use of a Quad-ellipse quartz heater controlled by a powerstat. A continual purge of the furnace with argon was used to prevent oxidation of the specimen.

For data collection, two X-Y recorders were used. One recorder was dedicated to recording a master plot of torsional load vs. torsional deflection of the entire test history. The second recorder was attached to a bucking system so only small portions of the test were recorded at any time. These small portions (chosen beforehand) can be greatly magnified and the data viewed in much greater detail. Usually, the modulus, change of strain rate, and the Bauschinger curve were recorded in this manner.

A nickel rod (0.250-inch diameter) was strained to 225% at 625° C in argon at a strain-rate of 1×10^{-4} in./in./sec. At the end of five revolutions, the program reversed the direction of torsion (Bauschinger test). Figures 3, 4, and 5 are scaled reproductions of actual test data.

All components of the system including the unique device for strain control have been checked out and are operational.

ACKNOLWEDGEMENTS

The technical advice of Robert Scott and Ralph Boling is gratefully acknowledged. This project would have been much more difficult without their assistance.

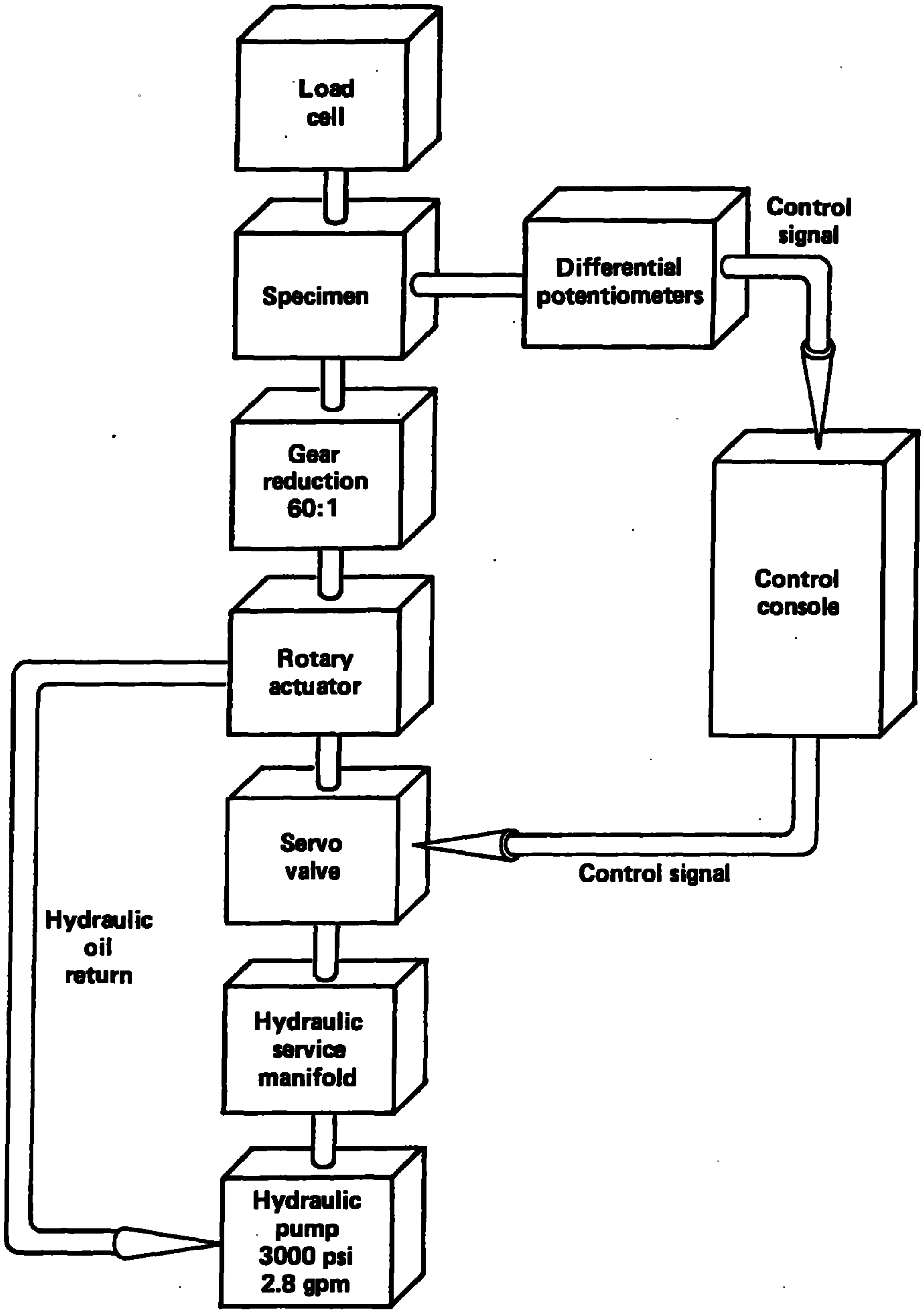

Figure 1. Torsion system

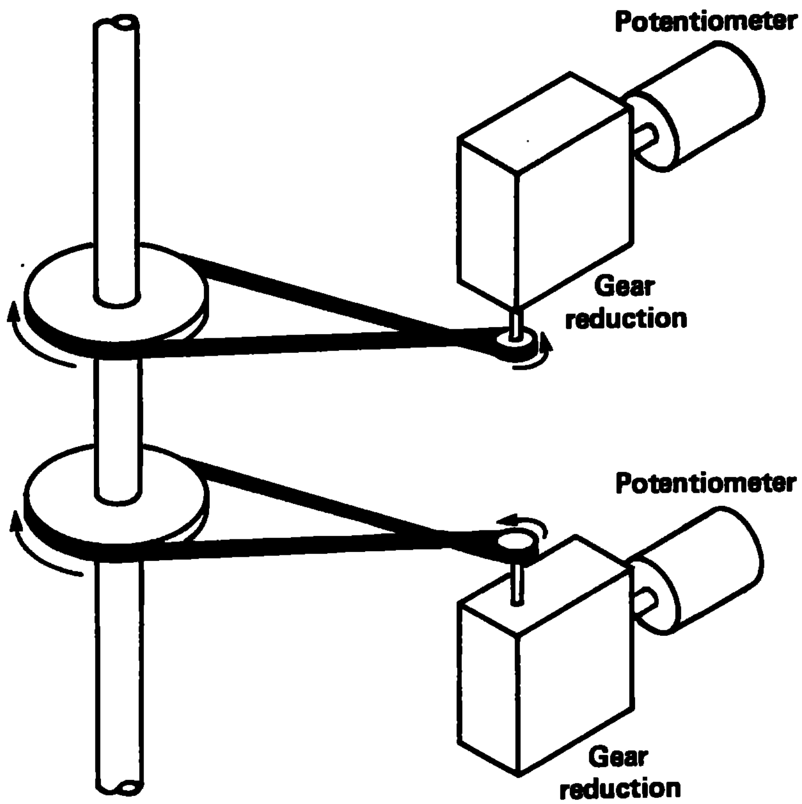

Figure 2. Strain gauge control for torsion system

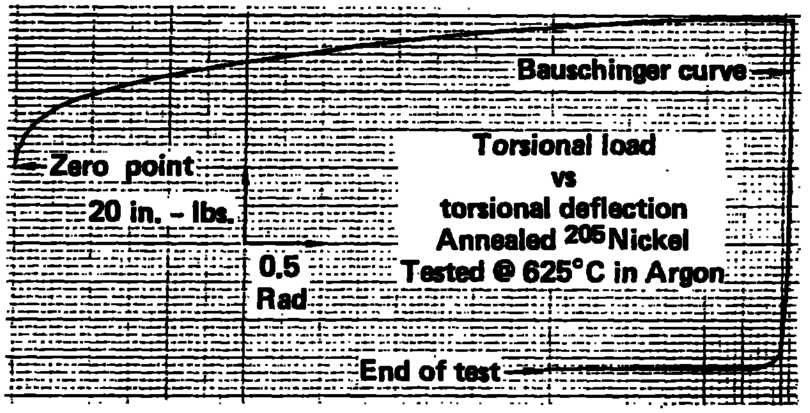
Bauschinger curve
Torsional load
vs
torsional deflection
Annealed 205 Nickel
Tested @ 625°C in Argon
Zero point
20 in. – lbs.
0.5
Rad
End of test

Figure 3

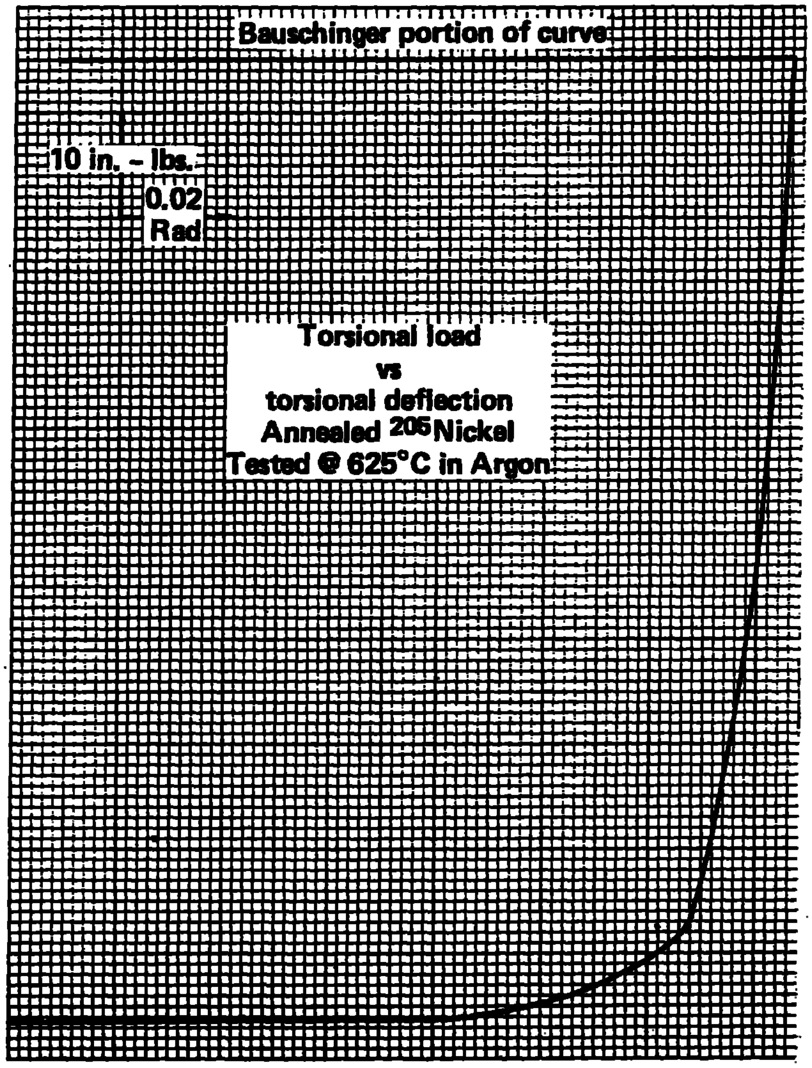
Bauschinger portion of curve
10 in. - lbs.
0.02
Rad
Torsional load
vs
torsional deflection
Annealed 205Nickel
Tested @ 625°C in Argon

Figure 4

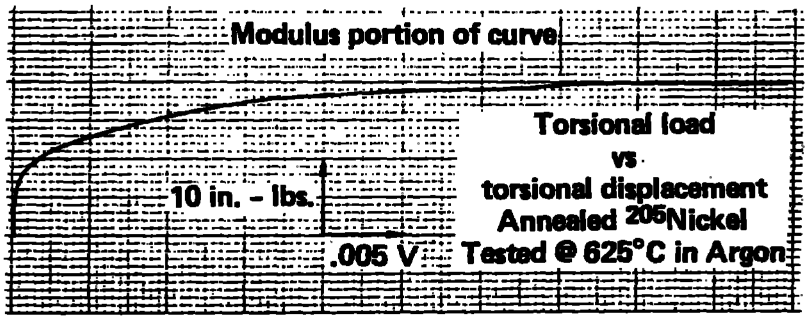
Modulus portion of curve
Torsional load
vs
torsional displacement
Annealed 205Nickel
Tested @ 625°C in Argon
10 in. - lbs.
.005 V

Figure 5